MONTHLY PROGRESS REPORT
MONTANA DOT "PERFORMANCE PREDICTION MODELS"
JUNE 2003

To:	**Susan Sillick, MDT**
	Jon Watson, MDT
Agency:	**Fugro-BRE, Inc.**
MDT Contract No.:	**HWY-30604-DT**
Performance Period:	**June 2003**
Prepared By:	**Brian Killingsworth, PE, Principal Investigator**
Date Prepared:	**June 30, 2003**

CURRENT MONTH WORK ACTIVITIES AND COMPLETED TASKS

PHASE I

Task 1 – Literature Review

Complete. A draft memorandum summarizing the models to be considered within this project was submitted to the Montana DOT (MDT) in October 2001. This memorandum will be updated when the calibration and validation of the 2002 Design Guide distress prediction models are made available.

Task 2 – Review of MT DOT Pavement-Related Data

Complete. However, Fugro-BRE will continue to monitor the LTPP database and update any missing data on the test sections with time.

Task 3 – Establish the Experimental Factorials

Complete.

Task 4 – Develop Work Plan for Monitoring and Testing

Complete. The long-term monitoring plan will be revised after the initial analyses of the data are complete under Tasks 6 and 7.

PHASE II

Task 5 – Presentation of Work Plan to MDT

Complete.

Task 6 – Implement Work Plan – Data Collection

On-going activities. For the 10 sites initially selected (Condon, Deerlodge/Beckhill, Silver City, Roundup, Lavina, Wolf Point, Ft. Belknap, Perma, Geyser, Hammond), all testing has been completed with the exception of a few of the CTB samples. Of the four Superpave sites for which materials have recently been received, Lothair, and Baum Rd. have tentatively been selected for inclusion in the testing program. However, testing for these two sites will begin after completion of tests on the first 10 sites.

<u>Unbound Materials: Base/Subbase and Subgrade (Subcontractor – Fugro-South, Houston, TX):</u> Unbound materials from the 10 sites selected in the experimental factorial (Condon, Deerlodge, Fort Belknap, Geyser, Hammond, Lavina, Perma, Roundup, Silver City, and Wolf Point) have been tested at the Fugro-South laboratory in Houston, Texas. Moisture-density curves at modified compactive effort (AASHTO T180) were derived for each of the 17 materials prior to testing. A repeated load resilient modulus test was performed for each material at optimum moisture content and maximum dry density (modified). The results of these tests have been presented in previous monthly reports.

<u>HMA Cores (Subcontractor – Advanced Asphalt Technologies, Sterling, VA):</u> All testing has been completed. There were two objectives for testing the HMA cores. The first was to obtain data for the Superpave Thermal Fracture analysis. This required low temperature creep and strength data at three temperatures. The second objective was to obtain resilient modulus data to compare with stiffness values obtained from the "Witczak et al." dynamic modulus predictive equation.

Three cores for each material were selected for low temperature creep testing. Each core was tested at three temperatures: -20^{o}C (-4^{o}F), -10^{o}C (14^{o}F), 0^{o}C (32^{o}F). Similarly, for resilient modulus, three cores were tested for each material, each core at three temperatures: 4^{o}C (39.2^{o}F), 16^{o}C (60.8^{o}F), and 14^{o}C (80.6^{o}F). Indirect tensile strength and strain to failure were obtained at the 6 temperatures used in the M_R and creep tests using 2 specimens per temperature (12 cores per material). Resilient modulus test results have been summarized in the previous monthly report.

Results of the indirect tensile strength test and strain at failure at 4^{o}, 16^{o}, and 27^{o}C were presented in the April-May 2003 monthly report. The report also included the results of the creep compliance data generated in the low temperature creep. Although the low temperature indirect strength test data is available, deriving the indirect tensile strength values from the raw test data is a rather complicated and time-consuming process. The results will be included in a later monthly report, as soon as they are available.

<u>CTB Cores (Subcontractors – Fugro South, Inc. Houston, TX; Texas Transportation Institute, College Station, TX):</u> The objective for testing the CTB cores was to obtain the elastic modulus of the material. However, the test protocol (ASTM C 469 - 94) requires 4 in. diameter by 8 in. length test cylinders to be used as test specimens. Cores more than 8 in. in length have been sent to the Fugro-South laboratory in Houston for coring and testing. Difficulties with coring from 6 in. diameter cores were still encountered and are due to insufficient binder content. Of the 4 materials sent to Houston (Roundup, Hammond, Wolf Point and Geyser), only two, Wolf Point and Geyser were tested. Although coring was attempted on all materials, the Roundup and Hammond cores could not be reduced to 4 in. diameter specimens. The setup used by Fugro-South in their attempts is illustrated in Figure 1.

Figure 1. CTB cores embedded in concrete slab

To avoid destroying the samples during coring due to insufficient confining/binder content, all original field cores have been embedded in a concrete slab and only then coring was attempted. While this procedure worked very well for the Wolf Point and Geyser CTB materials, it did not help with the Roundup and Hammond cores, as illustrated in Figures 2 and 3.

Figure 2. Difficulties Coring the Roundup CTB Material

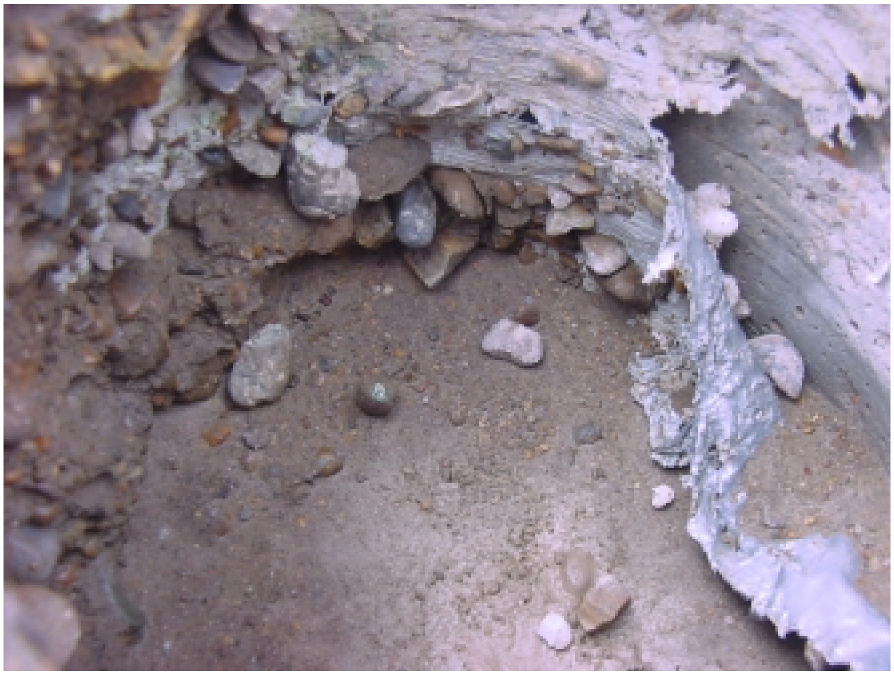


Figure 3. Difficulties Coring the Roundup CTB Material

For the Wolf Point and Geyser materials, four elastic modulus and compressive strength tests were performed for each. The deformation was measured with two clamp-mounted LVDTs at the middle half of the test specimen. The test setup is presented in Figure 4:

Figure 4. Test Setup for Elastic Modulus and Compressive Strength

The stress-strain curves obtained for the Wolf Point and Geyser materials are given in Figures 5 and 6. The four series on each plot correspond to the four specimens tested for each material:

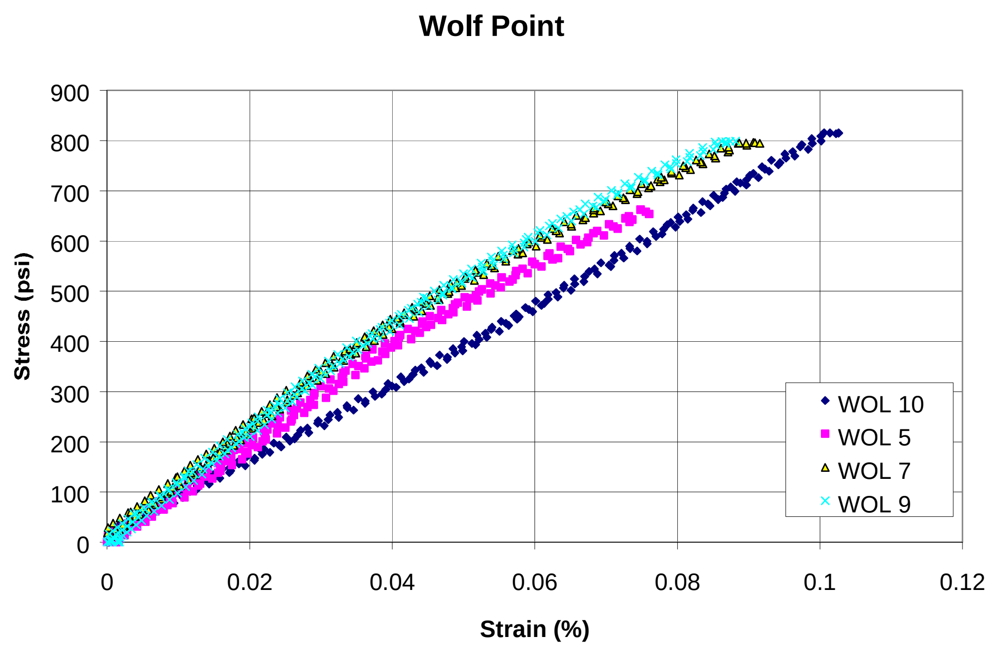


Figure 5. Stress-Strain Curve for Wolf Point CTB Material

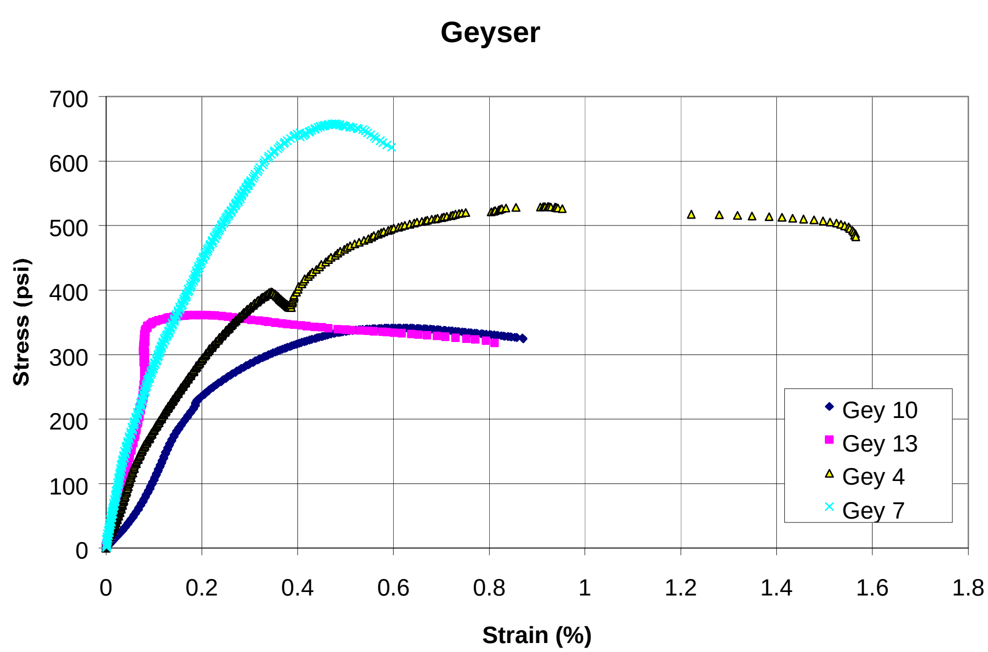


Figure 6. Stress-Strain Curve for Geyser CTB Material

According to the ASTM protocol (C 469-94), the elastic modulus is calculated as the chord modulus between the points corresponding to a longitudinal strain of $50*10^{-6}$ and a stress that equals 40 percent of the ultimate load (compressive strength). However, as illustrated in Figure 5, the ultimate load was higher than the capacity of the test frame for the Wolf Point Material. For Geyser, significant variability in the stress-strain curves and ultimate load is observed. To overcome these problems, for both materials, it was decided to calculate the modulus by isolating the initial straight part of the stress-strain curve (highest slope) as representative of the elastic response of the material. This procedure is similar to the one used in calculating/correcting the results of CBR tests. Using this approach, an average modulus value of 996 ksi with a standard deviation of 155 ksi (CV = 0.16) was obtained for Wolf Point. For the weaker Geyser material, an average modulus value of 289 ksi with a standard deviation of 104 ksi (CV = 0.36) was obtained.

CTB cores of less than 8 in. lengths have been sent to the Texas Transportation Institute (TTI) laboratory to be tested for indirect tensile strength and strain at failure. The indirect tensile strength can then be used to estimate the elastic modulus of the material; and it has the advantage that the test specimens are only 1 to 3 in. thick (6 in. diameter). The test specimens were obtained by sawing the CTB cores that are less than 8 in. long. In order to check the correlation between the elastic modulus measured at the Fugro laboratory and the indirect tensile strength measured at the TTI laboratory, available cores for the Roundup, Hammond, and Wolf Point CTB materials were sent to both labs.

Although not included in the initial testing plan, density tests will be performed on all CTB materials at the TTI laboratory. Density is a necessary input for any pavement response model and will be useful for the proper characterization of the Montana CTB materials. At this time, all specimen preparation (sawing) is completed and testing is about to commence.

Backcalculation of Deflections: The first round of deflection tests have been backcalculated and summarized. In addition, the second round of deflection testing has also been backcalculated utilizing the same pavement structure information as the Round 1 data. Using the backcalculated modulus values, the pavement structure was modeled as a linear elastic layered structure in ELSYM 5 and the states of stress in each layer were estimated under a load of equal magnitude with the one used by the Falling Weight Deflectometer (i.e., 9,000 lbf.). For unbound materials, the resilient modulus at the estimated states of stress was predicted using the 2002 Design Guide stress-dependent model. For the surface layer, the lab-measured resilient modulus values were used to develop a predictive model for resilient modulus as a function of air voids and temperature. The model was used to predict the lab M_R value at the temperature at which the FWD measurements were taken. Comparisons of the laboratory-derived values with FWD derived values were provided in the last monthly report. Further analysis of these comparisons will be completed for the Task 7 calibration.

Superpave Supplemental Sites: The project team has received samples from sites constructed with Superpave-designed hot mix and sampled by MDT during the time of construction. The purpose of adding these sections will be to incorporate pavements constructed with current MDT mixture design procedures. An inventory of the materials received to date was included in a previous monthly report. A testing plan will be developed once the testing for the initial 10 sites has been completed.

Field Investigation Report: A field investigation report has been completed by the project team and includes a summary of the distress surveys, field sampling results (cores, borings, and other geotechnical information), FWD deflections (Round 1 only), and longitudinal profiles from each of the supplemental sites.

A new series of distress surveys is under way for the 10 non-LTPP sites originally included in the experimental factorial and the additional 2 Superpave sites recently selected. The schedule for the manual distress surveys is given in Figure 7.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
16	17	18 M-LAVINA AM M-ROUNDUP PM	19 M-HAMMOND	20 M-WOLFPOINT
23 M-FORT BELKNAP AM M-LOTHAIR PM	24 M-GEYSER AM M-SILVER CITY PM	25 M-BAUM AM M-BECKHILL/DEERLODGE PM	26 M-PERMA AM M-CONDON PM	27

M-MANUAL DISTRESS SURVEYS

Figure 7. Manual Distress Survey Schedule, June 2003

The results of these surveys will be included in the next monthly report.

Supplemental Data: Fugro-BRE contacted Dr. Vince Janoo and obtained a copy of the seasonal data and draft report entitled "Performance of Montana Highway Pavements During Spring Thaw." This data will be used in analyzing the response and performance data that were monitored and obtained from other test sections.

Task 7 – Data Analyses and Calibration of Performance Prediction Models

The objectives of this task are to demonstrate the calibration technique required to develop and maintain the various model calibration coefficients that will be used by the department both now and in the future. As discussed with the MDT, four major distress types were considered in the experimental plan and thus require prediction models and calibration coefficients. These include fatigue cracking (both surface initiated and bottom initiated surface cracks), thermal cracking, rutting or permanent deformation, and ride quality.

The project team is currently awaiting release of the AASHTO 2002 Design Guide information, which is expected in the first half of 2003 before attempting any calibration of these models. However, the calibration technique (or the specific steps required to determine calibration coefficients) can still be demonstrated to MDT utilizing models similar in nature to the AASHTO 2002 Design Guide models. The project team is moving ahead with this demonstration portion of Task 7 with data obtained from the LTPP database and the supplemental sites.

The project team has met with Mr. Harold Von Quintus on several occasions and is working on completing the initial calibration effort. Issues discussed at these meetings include the supplemental site testing, model selection, LTPP data gathering, database population, traffic data summarization, and environmental data gathering. The following discusses these items separately.

<u>Calibration Database Development:</u> The initial steps required to populate the calibration and validation database have begun. The first step taken was to verify which LTPP data were missing since the last time it was checked. No significant changes in the available data were found.

Also, the status of the additional LTPP sections outside of, but adjacent to, Montana was verified. Each section was checked for sufficient data so that only those sections with adequate data are being utilized.

In addition, Structured Query Language (SQL) statements were developed for extracting the data required for model calibration from the LTPP IMS. These SQL statements will be provided to MDT so that future calibration efforts utilizing updated LTPP data may be streamlined.

A meeting was held with the database developer that included discussion of the specific requirements for the database. The database developer has restructured the database to make it more user-friendly, which will facilitate MDT using the database for further model calibration after this contract is complete. The draft database schema has been completed, reviewed, and checked, and population of the database has commenced. The draft database schema is included as Appendix A of this report (print on 8 ½" x 14" sheets).

<u>Environmental Data:</u> Montana climatic data will be utilized in the calibration effort. Specifically, the AASHTO 2002 environmental database will be used, which will include information for Montana and surrounding regions. However, it is also recommended that MDT include additional years of environmental data (up to 20 years) to better quantify the expected environmental conditions. The project team is incorporating tables into the calibration database to handle environmental data. This data will include rainfall and temperature information as well as in-situ moisture information for the appropriate environmental zones delineated in the State.

<u>Traffic Data:</u> A review of all the LTPP traffic tables has been initiated. The completeness of the data will be documented and the need for additional traffic information will be assessed.

Recommendations for the required traffic information have already been discussed among the project team, Mr. Von Quintus, and Dr. Mark Hallenbeck (who will continue gathering, reviewing, and assessing this data, especially in light of the initial calibration effort currently underway).

Task 8 – Final Report and Presentation of Results
No activity.

PROBLEMS / RECOMMENDED SOLUTIONS

No problems were encountered during last month and none are anticipated next month.

NEXT MONTH'S WORK PLAN

The activities planned for next month are listed below:

- Coordinate with MDT personnel on an as-needed basis.
- Continue testing materials that are outstanding.
- Continue analysis of all data collected at the LTPP and non-LTPP test sections.
- Continue with the initial calibration demonstration effort.

FINANCIAL STATUS

The Financial Summary I table shows the estimated expenses incurred during the reporting period.

The Financial Summary II table provides the total project expenditures by the Montana and FHWA fiscal years in comparison to the allocated funds for each fiscal year.

The Financial Summary III chart illustrates total expenditures by month for the project.

cc: Jim Moulthrop, Fugro-BRE
Dragos Andrei, Fugro-BRE
Amber Yau, Fugro-BRE
Veena Prabhakar, Fugro-BRE
Harold Von Quintus, ARA/ERES

Financial Summary I
Estimated Expenses for Reporting Period: Fugro-BRE

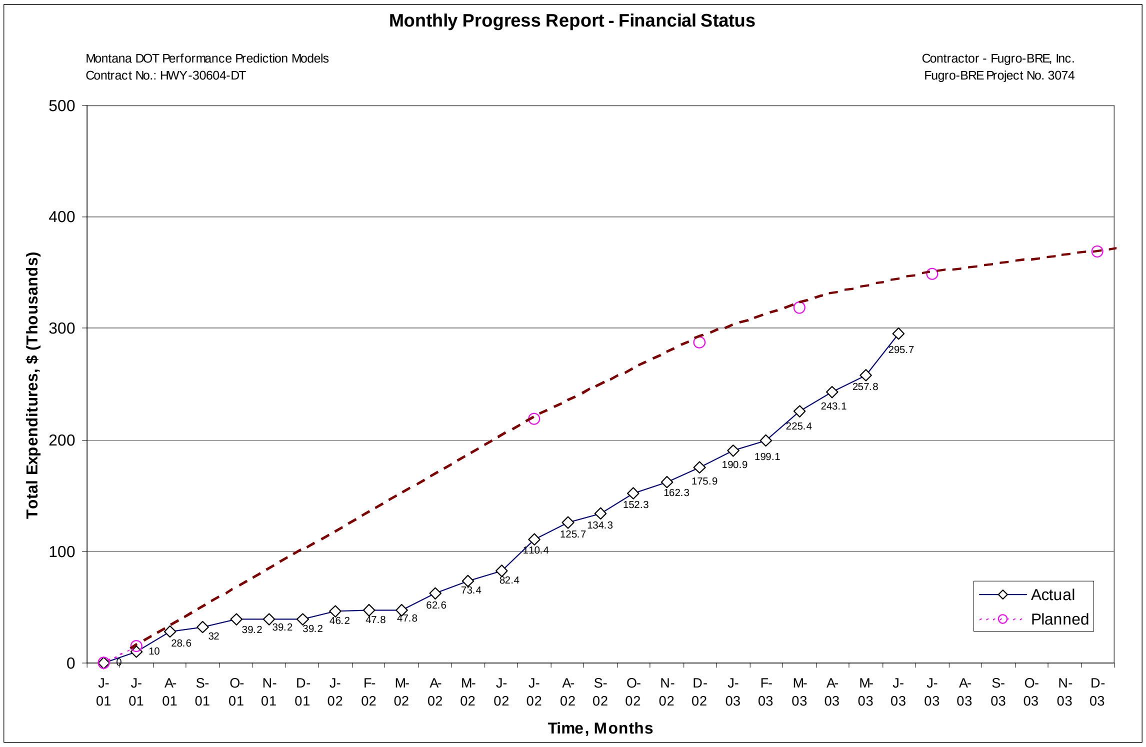
Cost Element	Cumulative Cost Jun 2001 - May 2003, $	Current Expenditures June 2003, $	Cumulative Costs Jun 2001 - June 2003, $
Direct Labor	54,320	6,281	60,602
Overhead	77,678	8,983	86,661
Consultants/Subcontractors	4,050		4,050
ERES/ARA	14,803	281	15,085
Parsons-Brinkerhoff	12,093	0	12,093
SME	523	0	523
Dr. Matthew Witczak	0	0	0
Dr. Mark Hallenbeck	3,130	0	3,129
Travel	10,827	0	10,827
Testing	52,958	18,900	71,859
Other Direct Costs	3,988	11	3,999
Fee	23,437	3,446	26,882
TOTAL	257,808	37,903	295,712

Financial Summary II
Total Expenditures by Fiscal Year: Montana and FHWA

Montana DOT Fiscal Year			FHWA Fiscal Year		
Fiscal Year	Allocated Funds Cumulative, $	Expenditures Cumulative, $	Fiscal Year	Allocated Funds Cumulative, $	Expenditures Cumulative, $
6/1-6/30 2001	15,000	*0	6/1-9/30 2001	65,000	31,996
7/1-6/30 2002	218,969	82,420	10/1-9/30 2002	258,969	102,303
7/1-6/30 2003	348,969	213,291	10/1-9/30 2003	358,969	161,412
7/1-6/30 2004	388,969	---	10/1-9/30 2004	398,969	---
7/1-6/30 2005	428,969	---	10/1-9/30 2005	438,969	---
7/1-6/30 2006	498,969	---	10/1-9/30 2006	498,969	---
TOTAL	498,969	295,712		498,969	295,712

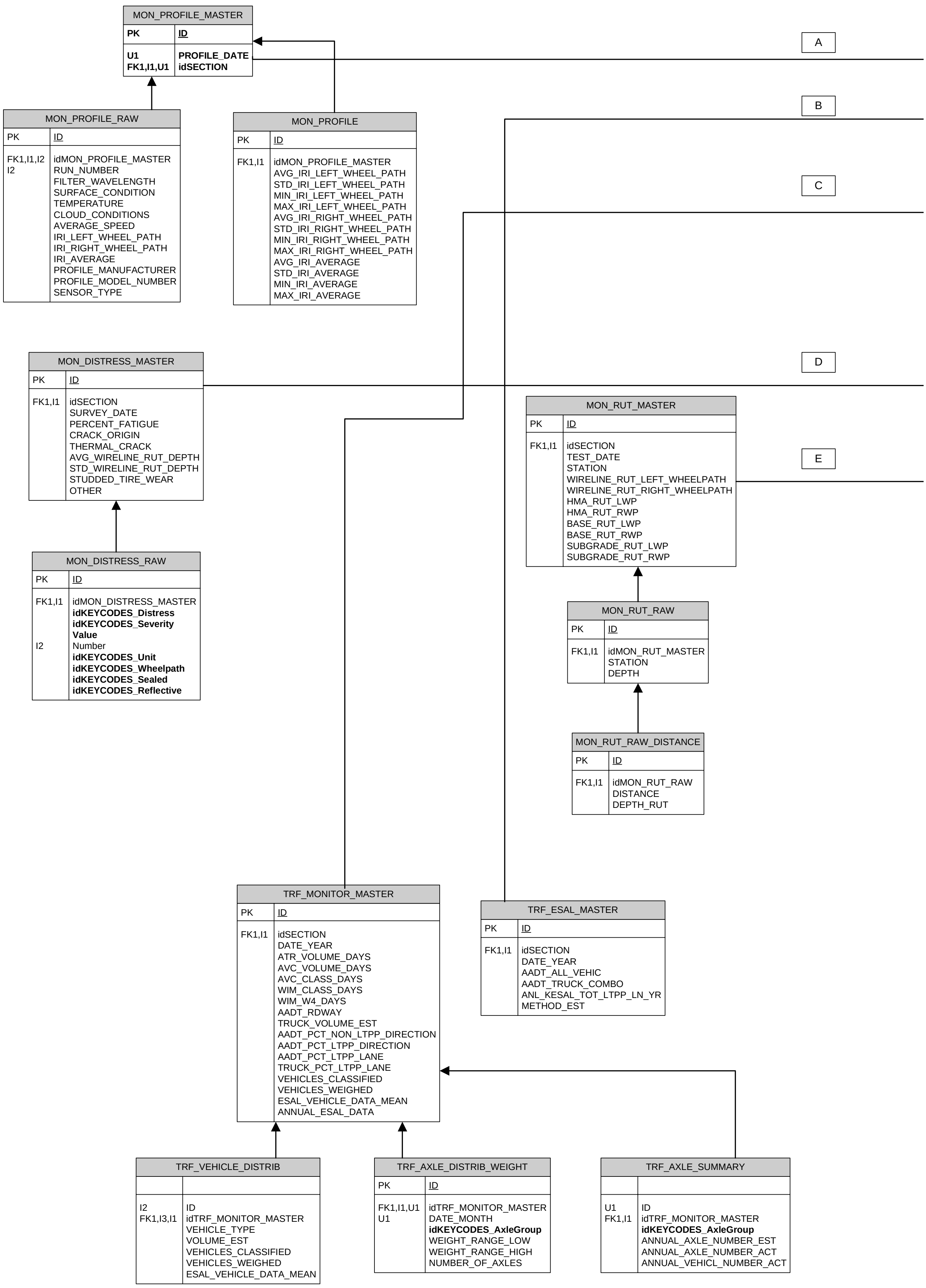
*June 2001 expenditures were combined with July 2001 expenditures.

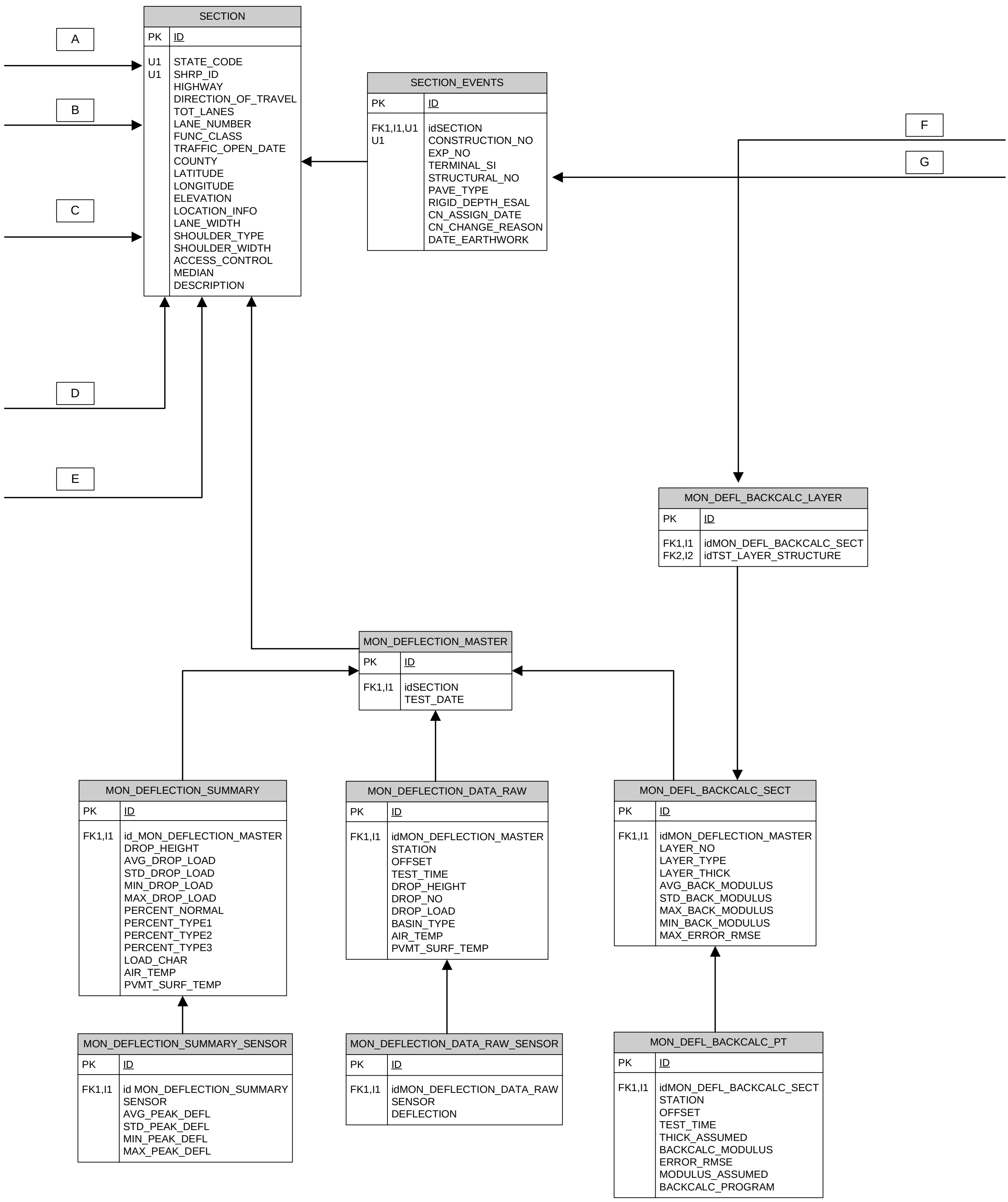
Financial Summary III:
Total Expenditures By Month

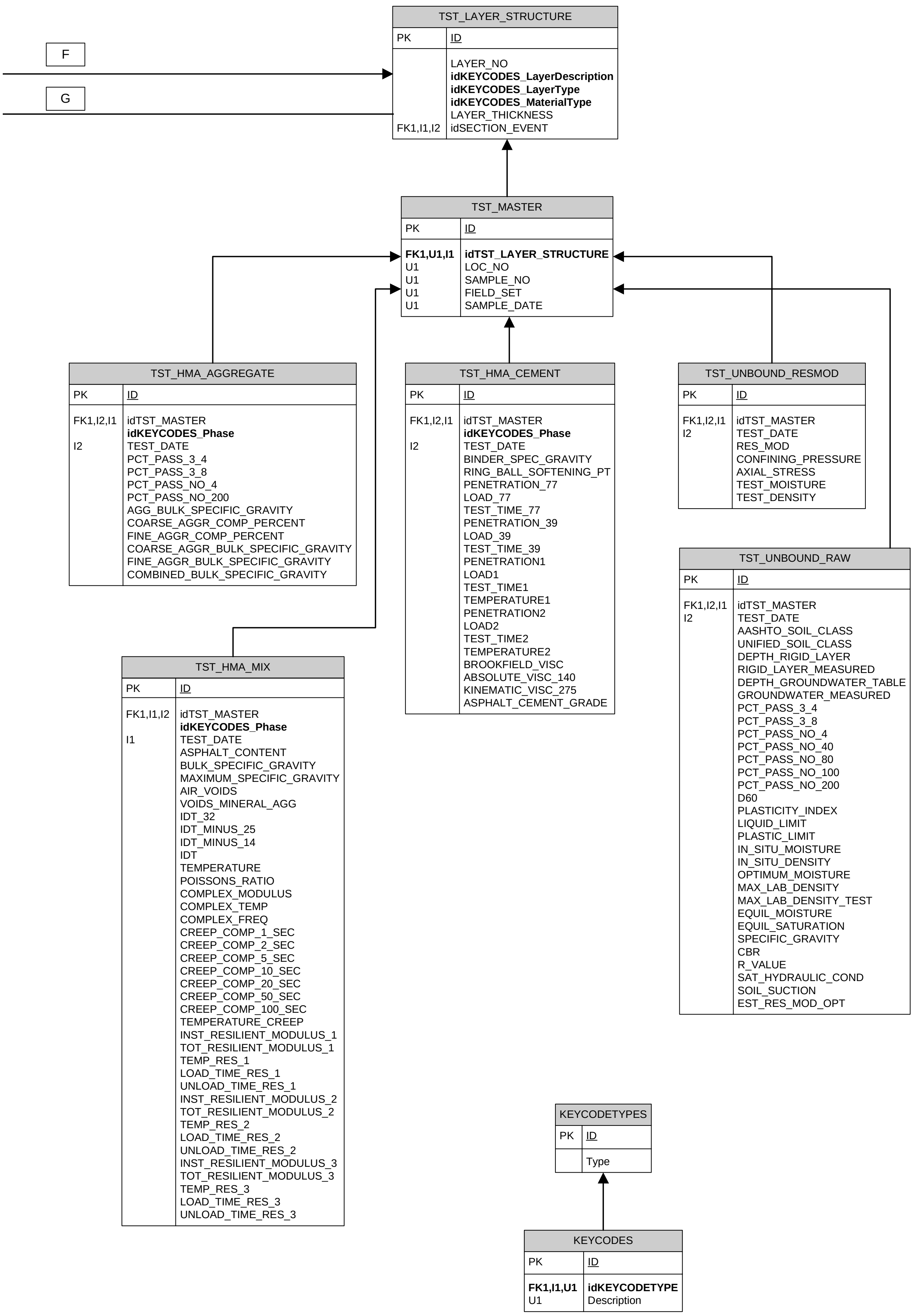


Appendix A

Montana Pavement Performance Models
Database Schema


MON_PROFILE_MASTER
PK ID
U1 PROFILE_DATE
FK1,I1,U1 idSECTION
A
B
C
D
E
MON_PROFILE_RAW
PK ID
FK1,I1,I2 idMON_PROFILE_MASTER
I2 RUN_NUMBER
FILTER_WAVELENGTH
SURFACE_CONDITION
TEMPERATURE
CLOUD_CONDITIONS
AVERAGE_SPEED
IRI_LEFT_WHEEL_PATH
IRI_RIGHT_WHEEL_PATH
IRI_AVERAGE
PROFILE_MANUFACTURER
PROFILE_MODEL_NUMBER
SENSOR_TYPE
MON_PROFILE
PK ID
FK1,I1 idMON_PROFILE_MASTER
AVG_IRI_LEFT_WHEEL_PATH
STD_IRI_LEFT_WHEEL_PATH
MIN_IRI_LEFT_WHEEL_PATH
MAX_IRI_LEFT_WHEEL_PATH
AVG_IRI_RIGHT_WHEEL_PATH
STD_IRI_RIGHT_WHEEL_PATH
MIN_IRI_RIGHT_WHEEL_PATH
MAX_IRI_RIGHT_WHEEL_PATH
AVG_IRI_AVERAGE
STD_IRI_AVERAGE
MIN_IRI_AVERAGE
MAX_IRI_AVERAGE
MON_DISTRESS_MASTER
PK ID
FK1,I1 idSECTION
SURVEY_DATE
PERCENT_FATIGUE
CRACK_ORIGIN
THERMAL_CRACK
AVG_WIRELINE_RUT_DEPTH
STD_WIRELINE_RUT_DEPTH
STUDDED_TIRE_WEAR
OTHER
MON_RUT_MASTER
PK ID
FK1,I1 idSECTION
TEST_DATE
STATION
WIRELINE_RUT_LEFT_WHEELPATH
WIRELINE_RUT_RIGHT_WHEELPATH
HMA_RUT_LWP
HMA_RUT_RWP
BASE_RUT_LWP
BASE_RUT_RWP
SUBGRADE_RUT_LWP
SUBGRADE_RUT_RWP
MON_DISTRESS_RAW
PK ID
FK1,I1 idMON_DISTRESS_MASTER
idKEYCODES_Distress
idKEYCODES_Severity
Value
I2 Number
idKEYCODES_Unit
idKEYCODES_Wheelpath
idKEYCODES_Sealed
idKEYCODES_Reflective
MON_RUT_RAW
PK ID
FK1,I1 idMON_RUT_MASTER
STATION
DEPTH
MON_RUT_RAW_DISTANCE
PK ID
FK1,I1 idMON_RUT_RAW
DISTANCE
DEPTH_RUT
TRF_MONITOR_MASTER
PK ID
FK1,I1 idSECTION
DATE_YEAR
ATR_VOLUME_DAYS
AVC_VOLUME_DAYS
AVC_CLASS_DAYS
WIM_CLASS_DAYS
WIM_W4_DAYS
AADT_RDWAY
TRUCK_VOLUME_EST
AADT_PCT_NON_LTPP_DIRECTION
AADT_PCT_LTPP_DIRECTION
AADT_PCT_LTPP_LANE
TRUCK_PCT_LTPP_LANE
VEHICLES_CLASSIFIED
VEHICLES_WEIGHED
ESAL_VEHICLE_DATA_MEAN
ANNUAL_ESAL_DATA
TRF_ESAL_MASTER
PK ID
FK1,I1 idSECTION
DATE_YEAR
AADT_ALL_VEHIC
AADT_TRUCK_COMBO
ANL_KESAL_TOT_LTPP_LN_YR
METHOD_EST
TRF_VEHICLE_DISTRIB
I2 ID
FK1,I3,I1 idTRF_MONITOR_MASTER
VEHICLE_TYPE
VOLUME_EST
VEHICLES_CLASSIFIED
VEHICLES_WEIGHED
ESAL_VEHICLE_DATA_MEAN
TRF_AXLE_DISTRIB_WEIGHT
PK ID
FK1,I1,U1 idTRF_MONITOR_MASTER
U1 DATE_MONTH
idKEYCODES_AxleGroup
WEIGHT_RANGE_LOW
WEIGHT_RANGE_HIGH
NUMBER_OF_AXLES
TRF_AXLE_SUMMARY
U1 ID
FK1,I1 idTRF_MONITOR_MASTER
idKEYCODES_AxleGroup
ANNUAL_AXLE_NUMBER_EST
ANNUAL_AXLE_NUMBER_ACT
ANNUAL_VEHICL_NUMBER_ACT


A
B
C
D
E
F
G
SECTION
PK ID
U1 STATE_CODE
U1 SHRP_ID
HIGHWAY
DIRECTION_OF_TRAVEL
TOT_LANES
LANE_NUMBER
FUNC_CLASS
TRAFFIC_OPEN_DATE
COUNTY
LATITUDE
LONGITUDE
ELEVATION
LOCATION_INFO
LANE_WIDTH
SHOULDER_TYPE
SHOULDER_WIDTH
ACCESS_CONTROL
MEDIAN
DESCRIPTION
SECTION_EVENTS
PK ID
FK1,I1,U1 idSECTION
U1 CONSTRUCTION_NO
EXP_NO
TERMINAL_SI
STRUCTURAL_NO
PAVE_TYPE
RIGID_DEPTH_ESAL
CN_ASSIGN_DATE
CN_CHANGE_REASON
DATE_EARTHWORK
MON_DEFL_BACKCALC_LAYER
PK ID
FK1,I1 idMON_DEFL_BACKCALC_SECT
FK2,I2 idTST_LAYER_STRUCTURE
MON_DEFLECTION_MASTER
PK ID
FK1,I1 idSECTION
TEST_DATE
MON_DEFLECTION_SUMMARY
PK ID
FK1,I1 id_MON_DEFLECTION_MASTER
DROP_HEIGHT
AVG_DROP_LOAD
STD_DROP_LOAD
MIN_DROP_LOAD
MAX_DROP_LOAD
PERCENT_NORMAL
PERCENT_TYPE1
PERCENT_TYPE2
PERCENT_TYPE3
LOAD_CHAR
AIR_TEMP
PVMT_SURF_TEMP
MON_DEFLECTION_DATA_RAW
PK ID
FK1,I1 idMON_DEFLECTION_MASTER
STATION
OFFSET
TEST_TIME
DROP_HEIGHT
DROP_NO
DROP_LOAD
BASIN_TYPE
AIR_TEMP
PVMT_SURF_TEMP
MON_DEFL_BACKCALC_SECT
PK ID
FK1,I1 idMON_DEFLECTION_MASTER
LAYER_NO
LAYER_TYPE
LAYER_THICK
AVG_BACK_MODULUS
STD_BACK_MODULUS
MAX_BACK_MODULUS
MIN_BACK_MODULUS
MAX_ERROR_RMSE
MON_DEFLECTION_SUMMARY_SENSOR
PK ID
FK1,I1 id MON_DEFLECTION_SUMMARY
SENSOR
AVG_PEAK_DEFL
STD_PEAK_DEFL
MIN_PEAK_DEFL
MAX_PEAK_DEFL
MON_DEFLECTION_DATA_RAW_SENSOR
PK ID
FK1,I1 idMON_DEFLECTION_DATA_RAW
SENSOR
DEFLECTION
MON_DEFL_BACKCALC_PT
PK ID
FK1,I1 idMON_DEFL_BACKCALC_SECT
STATION
OFFSET
TEST_TIME
THICK_ASSUMED
BACKCALC_MODULUS
ERROR_RMSE
MODULUS_ASSUMED
BACKCALC_PROGRAM


F
G
TST_LAYER_STRUCTURE
PK
ID
LAYER_NO
idKEYCODES_LayerDescription
idKEYCODES_LayerType
idKEYCODES_MaterialType
LAYER_THICKNESS
FK1,I1,I2
idSECTION_EVENT
TST_MASTER
PK
ID
FK1,U1,I1
U1
U1
U1
U1
idTST_LAYER_STRUCTURE
LOC_NO
SAMPLE_NO
FIELD_SET
SAMPLE_DATE
TST_HMA_AGGREGATE
PK
ID
FK1,I2,I1
I2
idTST_MASTER
idKEYCODES_Phase
TEST_DATE
PCT_PASS_3_4
PCT_PASS_3_8
PCT_PASS_NO_4
PCT_PASS_NO_200
AGG_BULK_SPECIFIC_GRAVITY
COARSE_AGGR_COMP_PERCENT
FINE_AGGR_COMP_PERCENT
COARSE_AGGR_BULK_SPECIFIC_GRAVITY
FINE_AGGR_BULK_SPECIFIC_GRAVITY
COMBINED_BULK_SPECIFIC_GRAVITY
TST_HMA_CEMENT
PK
ID
FK1,I2,I1
I2
idTST_MASTER
idKEYCODES_Phase
TEST_DATE
BINDER_SPEC_GRAVITY
RING_BALL_SOFTENING_PT
PENETRATION_77
LOAD_77
TEST_TIME_77
PENETRATION_39
LOAD_39
TEST_TIME_39
PENETRATION1
LOAD1
TEST_TIME1
TEMPERATURE1
PENETRATION2
LOAD2
TEST_TIME2
TEMPERATURE2
BROOKFIELD_VISC
ABSOLUTE_VISC_140
KINEMATIC_VISC_275
ASPHALT_CEMENT_GRADE
TST_UNBOUND_RESMOD
PK
ID
FK1,I2,I1
I2
idTST_MASTER
TEST_DATE
RES_MOD
CONFINING_PRESSURE
AXIAL_STRESS
TEST_MOISTURE
TEST_DENSITY
TST_UNBOUND_RAW
PK
ID
FK1,I2,I1
I2
idTST_MASTER
TEST_DATE
AASHTO_SOIL_CLASS
UNIFIED_SOIL_CLASS
DEPTH_RIGID_LAYER
RIGID_LAYER_MEASURED
DEPTH_GROUNDWATER_TABLE
GROUNDWATER_MEASURED
PCT_PASS_3_4
PCT_PASS_3_8
PCT_PASS_NO_4
PCT_PASS_NO_40
PCT_PASS_NO_80
PCT_PASS_NO_100
PCT_PASS_NO_200
D60
PLASTICITY_INDEX
LIQUID_LIMIT
PLASTIC_LIMIT
IN_SITU_MOISTURE
IN_SITU_DENSITY
OPTIMUM_MOISTURE
MAX_LAB_DENSITY
MAX_LAB_DENSITY_TEST
EQUIL_MOISTURE
EQUIL_SATURATION
SPECIFIC_GRAVITY
CBR
R_VALUE
SAT_HYDRAULIC_COND
SOIL_SUCTION
EST_RES_MOD_OPT
TST_HMA_MIX
PK
ID
FK1,I1,I2
I1
idTST_MASTER
idKEYCODES_Phase
TEST_DATE
ASPHALT_CONTENT
BULK_SPECIFIC_GRAVITY
MAXIMUM_SPECIFIC_GRAVITY
AIR_VOIDS
VOIDS_MINERAL_AGG
IDT_32
IDT_MINUS_25
IDT_MINUS_14
IDT
TEMPERATURE
POISSONS_RATIO
COMPLEX_MODULUS
COMPLEX_TEMP
COMPLEX_FREQ
CREEP_COMP_1_SEC
CREEP_COMP_2_SEC
CREEP_COMP_5_SEC
CREEP_COMP_10_SEC
CREEP_COMP_20_SEC
CREEP_COMP_50_SEC
CREEP_COMP_100_SEC
TEMPERATURE_CREEP
INST_RESILIENT_MODULUS_1
TOT_RESILIENT_MODULUS_1
TEMP_RES_1
LOAD_TIME_RES_1
UNLOAD_TIME_RES_1
INST_RESILIENT_MODULUS_2
TOT_RESILIENT_MODULUS_2
TEMP_RES_2
LOAD_TIME_RES_2
UNLOAD_TIME_RES_2
INST_RESILIENT_MODULUS_3
TOT_RESILIENT_MODULUS_3
TEMP_RES_3
LOAD_TIME_RES_3
UNLOAD_TIME_RES_3
KEYCODETYPES
PK
ID
Type
KEYCODES
PK
ID
FK1,I1,U1
U1
idKEYCODETYPE
Description